SH7125, SH7085

MCRP05: Brushless AC Motor Control Reference Platform

Introduction

This document contains the description of the Motor Control Reference Platform [MCRP05] based on the powerful 32-bit RISC MCU SH7125 or SH7085. The SH family is offering unique set of peripherals to drive any motors and is featuring several protection features for industrial usage.

This platform controls a sensorless 3-phase Brushless Sinusoidal Synchronous motor inverter by using advanced Field Oriented Control algorithm (FOC).

The motor used is a Brushless motor called also Permanent Magnet motor (PMAC) or PMSM or BLAC.

The system is in closed loop as the current detection is done via a single shunt (three shunts is optional) which offers a very low cost solution and avoid any expensive encoder or current sensor.

The main focus applications are compressors, air conditioning, fans, industrial drives, washer, etc. The platform is flexible enough to develop any application using Brushless motor (synchronous & asynchronous).

The main features are:

1) Sensorless [No need of tachometer or encoder sensors]
2) High Speed
3) High efficiency [Due to the vector-type motor control]
4) Low noise [Due to the high reachable switching frequency and to the optimal alignment]
5) Low Cost [Due to high integration and to reduced component count]
6) High Reliability [Due to high integration and to reduced component count]

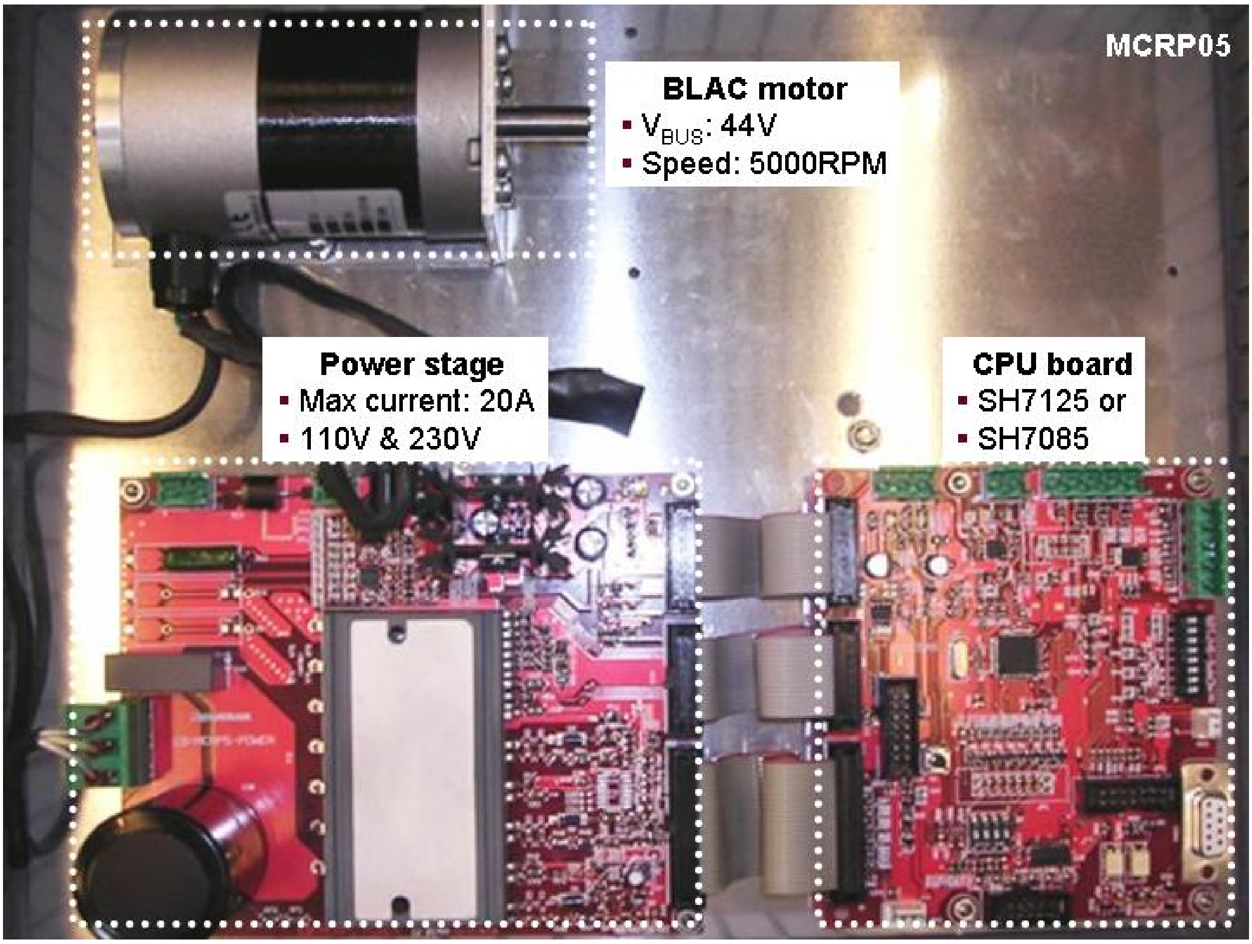
Content

Platform Overview: Hardware description

The MCRP05 is mainly divided into three parts:

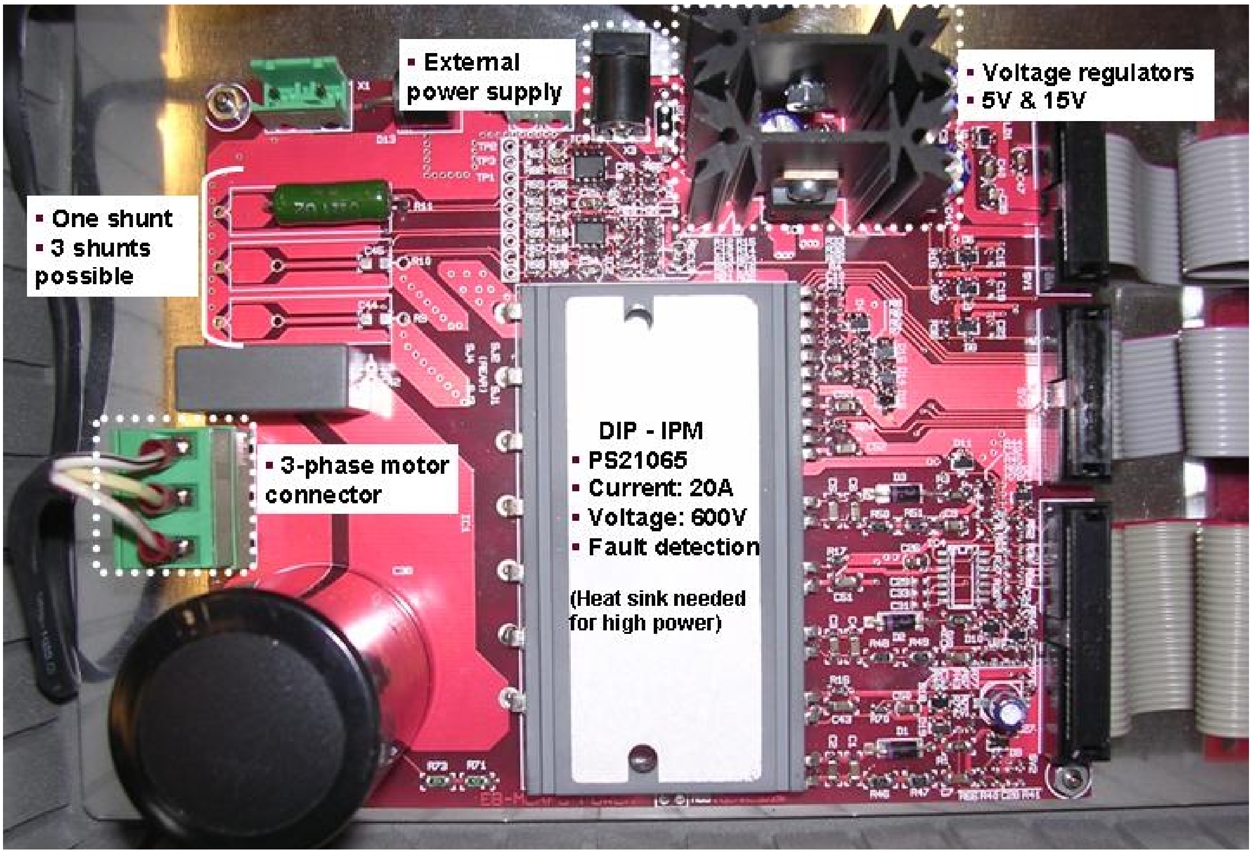
1) CPU board
2) Power stage
3) Low voltage demo system BLAC motor

The user interface is the standard user interface used for any Motor Control platform from Renesas.

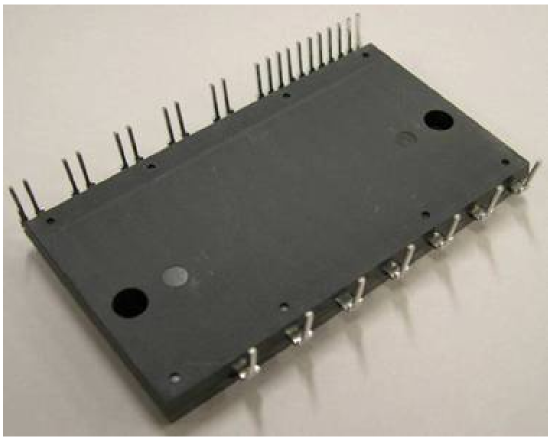


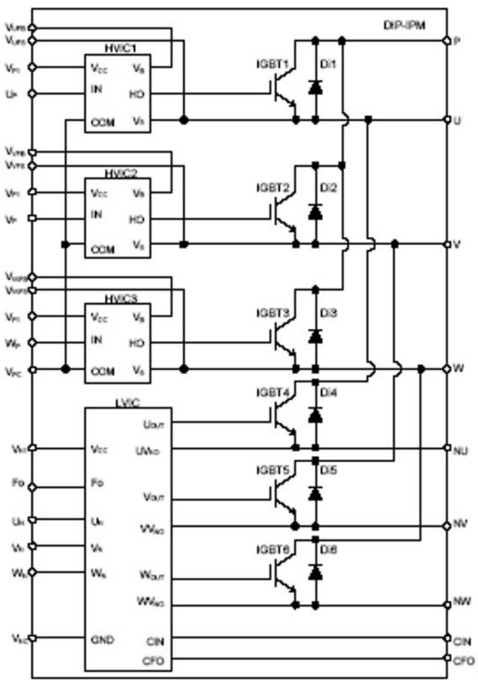
Furthermore, the MCRP05 can be fully controlled via a dedicated serial PC interface. The parameters may be changed via the GUI software after connection to the target.

Platform Overview: Power Stage description



The Power stage is based on the Intelligent Power Module called DIP-IPM 20A/600V from Mitsubishi: PS21065.





The IPM is constituted with six IGBTs and integrates the IGBT drivers & a reliable protection function:

- For upper-arm IGBTs: drive circuit, high voltage isolated high-speed level shifting, low voltage

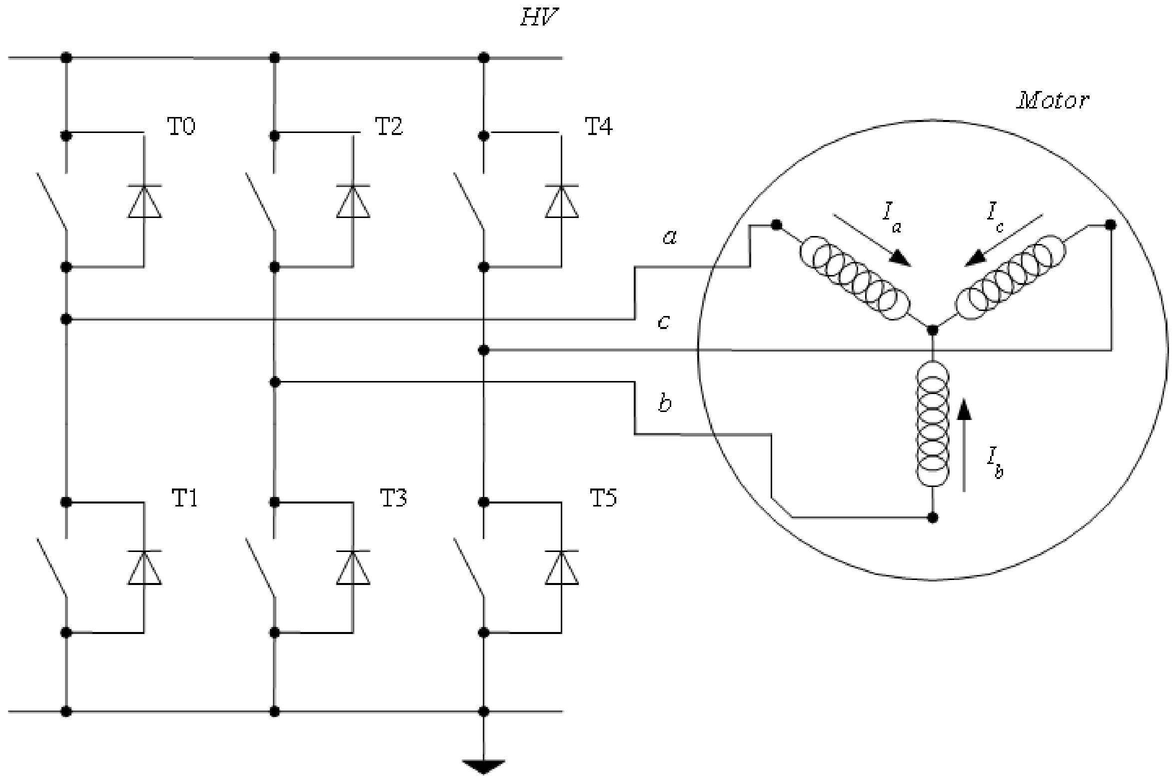
detection, short circuit protection (fault signal)

- For lower-arm IGBTs: drive circuit, low voltage detection, short circuit protection (fault signal)

- Fault signalling: corresponding to a short circuit fault (lower-side IGBT) or low voltage fault (lower-side IGBT). Such feature is quite appreciated for debug purposes.

- Input interface: 5V line CMOS/TTL compatible, Schmitt trigger circuit.

The IPM is a very reliable solution, low cost with a long life and ensures short dead time for our application.



The MCRP05 power stage is powered via the external 24V power supply. No rectifier for higher voltages is available on the board but any rectified voltage up to 400V can be supplied via the connector **X1** of the power board.

For any signals testing an isolated oscilloscope is mandatory to avoid any electrical shocks when a high voltage is supplied to the power stage.

Current detection methods:

The power stage board is fully working in the following modes:

1) Three Shunts current detection
2) Single Shunt current detection

1) The three shunts configuration allow higher PWM frequency because the influence of dead time versus PWM period is not significant for the sensorless algorithm.
2) In the three shunts configuration the maximum PWM frequency is the following:
    a. $F_{clock} = 80MHz$ → 1/35µs → $F_{PWM\ max.} = 28.5kHz$
    b. $F_{clock} = 50MHz$ → 1/56µs → $F_{PWM\ max.} = 17.8kHz$
3) All the previous data are calculated supposing that all the control loops are executed each PWM period, higher frequency can be reached if control loop frequency is slower than PWM frequency. In normal industrial application 3KHz control loop frequency is normally used.

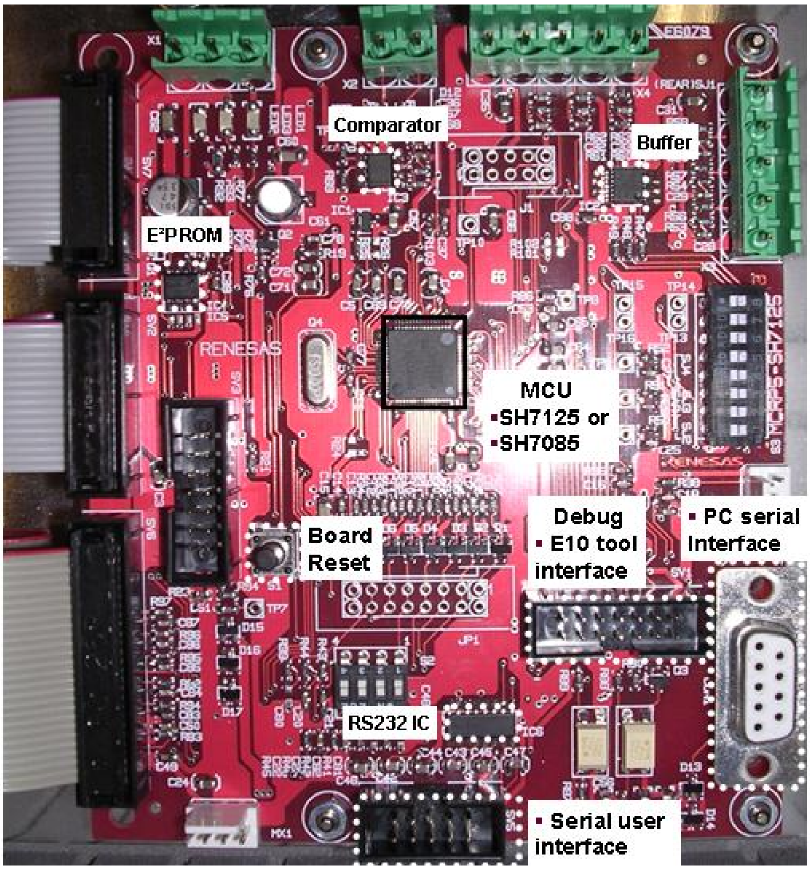
    The MCRP05 is offering one alternative: either **3KHz** or **10KHz** to offer a very high dynamics to the system.

4) The single shunt configuration forces the designer to reduce the PWM frequency.
    a. The PWM frequency must be reduced if the load dynamics is higher.
    b. On typical high voltage motors the max. reachable frequency is less than 15kHz.
    c. The maximum PWM frequency is reversely proportional to the needed dead-time.
    d. The bigger is the dead-time vs. the PWM period the bigger is the “hidden time” that causes wrong control [wrong alignment between mechanical phase and electrical phase] in case of high dynamic load.
    e. The MCRP05 is offering the choice between 10KHz or 20KHz.

Platform Overview: CPU Board

The CPU board is available in two models:

1) SH7085 [Maximum clock frequency: 80MHz]
2) SH7125 [Maximum clock frequency: 40MHz]



MCRP05 has been developed in order to demonstrate the excellent performances of SH2/SH2A cores in combination with state of the art motor control dedicated peripherals (MTU2 PWM module including dead-time insertion & compensation). Please find below the detailed features of each MCU.

The main purpose of this board is to drive Brushless AC [PMAC, 180°] motors in sensorless both using single-shunt current reading technique and also using three shunts current reading technique.

MCRP05 software can be modified to drive 3-phase induction motors (asynchronous motors) in sensorless mode with very high performances using FOC algorithm.

Please find below the main MCU features:

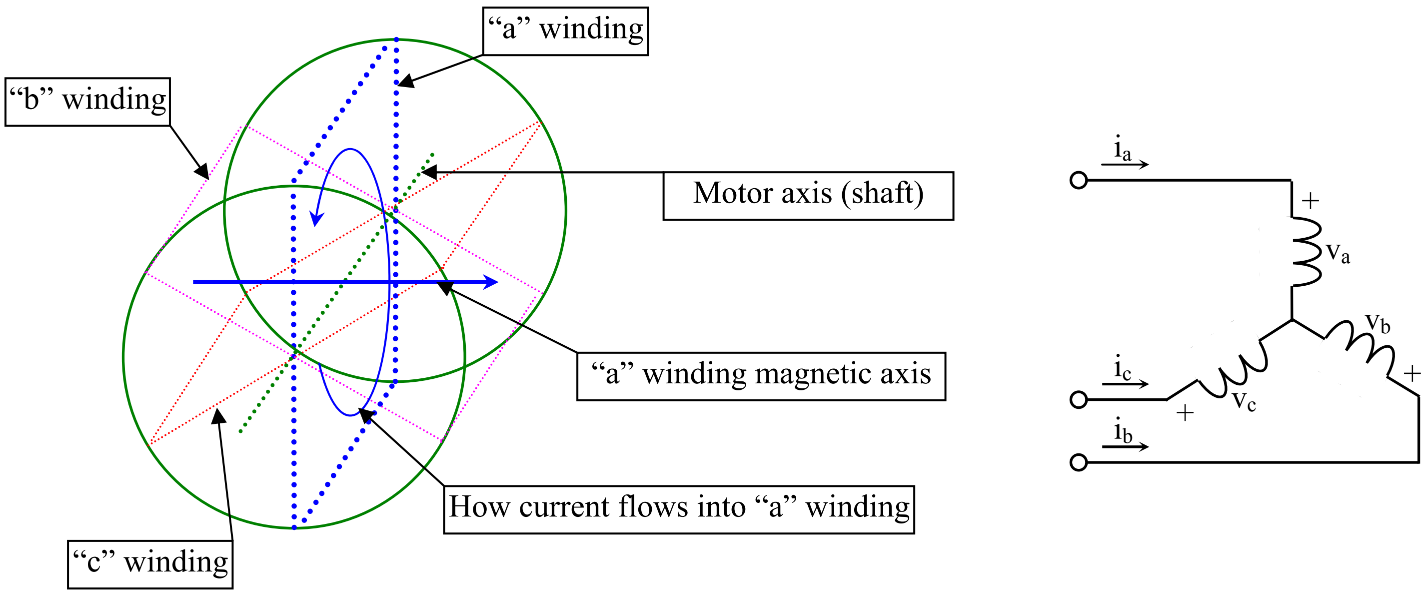
	SH7125	SH7085
CPU Core		
Internal clock	50MHz	80MHz
MIPS	65MIPS	110MIPS
MUL timing	20ns	12.5ns
DIV	1.9µs	1.2µs
Saturation Arithmetic	Yes	Yes
Memory		
Flash	64k / 128k	256k
RAM	8K	16K
External RAM	No, Single Chip	Yes BSC
Peripherals		
3 Phase PWM unit	One	Two
PWM fault input	Yes, POE	Yes, POE
MTU2S second PWM	No	Yes
Input capture	19	
PWM Resolution (bit @ > 15kHz)	>10	> 11 [MTU2] > 12 [MTU2S]
A/D converter resolution	10-bit	10-bit
A/D channels	8	12
A/D conversion time	2µs	2µs
A/D module number	2 x S/H modules	3 x S/H modules
A/D sweep mode	Yes	Yes
Communication interfaces		
UART (asynchronous)	3	3
DTC	No	Yes
Code security for On-Chip Flash	Yes	Yes
Watchdog Timer	Yes	Yes
Independent clock for WDT	Yes	Yes

Permanent Magnet Brushless motor model

The synchronous permanent magnets motor (sinusoidal brushless motor) is widely used in the industry. More & more home appliance makers are now using such brushless motor, mainly because of the intrinsic motor efficiency.

The permanent magnet motor is made with few components:

1. A *stator* formed by stacking sheared metal plates where internally the copper wiring is wound, constructing the stator winding
2. A *rotor* in which permanent magnets are fixed
3. Two covers with ball bearings that keep together the stator and the rotor; the rotor is free to rotate inside the stator



Stator windings schematic

The working principle is quite simple: if we supply the motor with a three-phase system of sinusoidal voltages, at constant frequency, in the stator windings flows sinusoidal currents, which create a rotating magnetic field.
The permanent magnets in the rotor tend to stay aligned with the rotating field, so the rotor rotates at synchronous speed.
The main challenge in driving this type of motor is to know the rotor position in real-time, so mainly implementation are using a position sensor or a speed sensor.
In our implementation, the system is using either one or three shunts to detect the rotor position in real-time.

Let's analyse the motor from a mathematic point of view.
If we apply three voltages $v_a(t)$, $v_b(t)$, $v_c(t)$ to the stator windings, the relations between phase voltages and currents are:

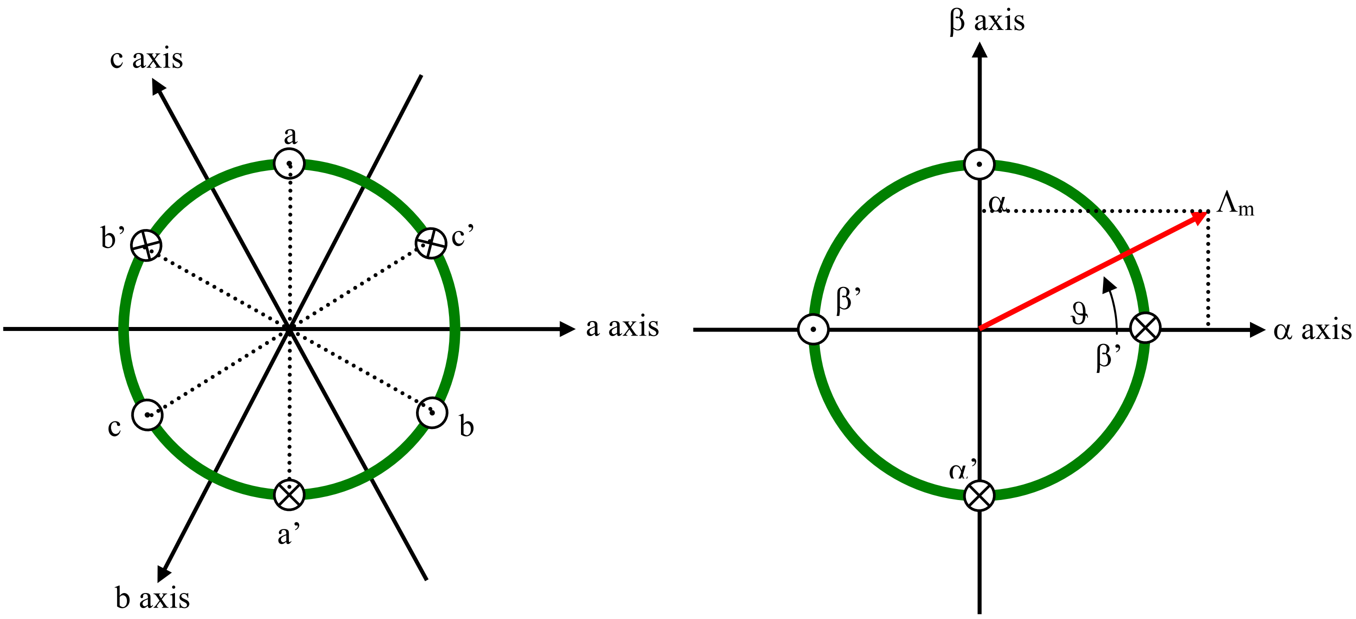
$$v_a = R_S i_a + \frac{d\lambda_a}{dt}$$

$$v_b = R_S i_b + \frac{d\lambda_b}{dt}$$

$$v_c = R_S i_c + \frac{d\lambda_c}{dt}$$

- λ_i is the magnetic flux linkage with the i-th stator winding
- R_S is the stator phase resistance (the resistance of one of the stator windings)

The magnetic flux linkages λ_i are composed by two items, one due to the stator currents, one to the permanent magnets.
The permanent magnet creates a magnetic field that is constant in amplitude and fixed in position in respect to the rotor.



Real axes (a, b, c) and equivalent ones (α, β); a fixed amplitude vector can be completely determined by its position respect the (α, β) system (angle ϑ)

This magnetic field can be represented by vector Λ_m whose position in respect to the stator is determined by the angle ϑ between the vector direction and the stator reference frame.
The contribution of the permanent magnets in the flux linkages depends on the relative position of the rotor and the stator represented by the mechanical-electric angle ϑ.

It is, in every axis, the projection of the constant flux vector Λ_m in the direction of the axis:

$$\lambda_a = Li_a + \Lambda_m \cos(\vartheta)$$
$$\lambda_b = Li_b + \Lambda_m \cos(\vartheta - 2\pi/3)$$
$$\lambda_c = Li_c + \Lambda_m \cos(\vartheta - 4\pi/3)$$

Supposing that the rotor is rotating at constant speed ω (that is: $\vartheta(t) = \omega t$) the flux linkages derivatives can be calculated, and we obtain:

$$v_a = R_S i_a + L\frac{di_a}{dt} - \omega\Lambda_m \sin(\vartheta)$$
$$v_b = R_S i_b + L\frac{di_b}{dt} - \omega\Lambda_m \sin(\vartheta - 2\pi/3)$$
$$v_c = R_S i_b + L\frac{di_b}{dt} - \omega\Lambda_m \sin(\vartheta - 4\pi/3)$$

A “three phases system” may be represented by an equivalent “two phases system”. So the by using specific transformations, our three equations system is equivalent to a two equations system. It is basically a mathematical representation in a new reference coordinates system.

In the two phases (α,β) fixed system the above equations become:

$$v_\alpha = R_S i_\alpha + \frac{d\lambda_\alpha}{dt}$$
$$v_\beta = R_S i_\beta + \frac{d\lambda_\beta}{dt}$$

For the magnetic field equations, we got:

$$\lambda_\alpha = Li_\alpha + \lambda_{\alpha m} = Li_\alpha + \Lambda_m \cos(\vartheta)$$
$$\lambda_\beta = Li_\beta + \lambda_{\beta m} = Li_\beta + \Lambda_m \sin(\vartheta)$$

After performing derivation:

$$\frac{d\lambda_\alpha}{dt} = L\frac{di_\alpha}{dt} - \omega\Lambda_m \sin(\vartheta) = L\frac{di_\alpha}{dt} - \omega\lambda_{\beta m}$$
$$\frac{d\lambda_\beta}{dt} = L\frac{di_\beta}{dt} + \omega\Lambda_m \cos(\vartheta) = L\frac{di_\beta}{dt} + \omega\lambda_{\alpha m}$$

Finally, we obtain for the voltages in (α,β) system:

$$v_\alpha = R_S i_\alpha + L\frac{di_\alpha}{dt} - \omega\lambda_{\beta m}$$

$$v_\beta = R_S i_\beta + L\frac{di_\beta}{dt} + \omega\lambda_{\alpha m}$$

A second reference frame is used to represent the equations as the frame is turning at the rotor speed. So the “d” axis is chosen in the direction of the magnetic vector Λ_m, and with the “q” axis orthogonal to the “d” axis. The new reference system is (d,q).

The reference frame transformations from the (α,β) system to the (d,q) system depends on the instantaneous position angle ϑ

So we obtain two inter-dependant equation in the (d,q) system:

$$v_d = R_S i_d + L\frac{di_d}{dt} - \omega L i_q$$

$$v_q = R_S i_q + L\frac{di_q}{dt} + \omega L i_d + \omega\Lambda_m$$

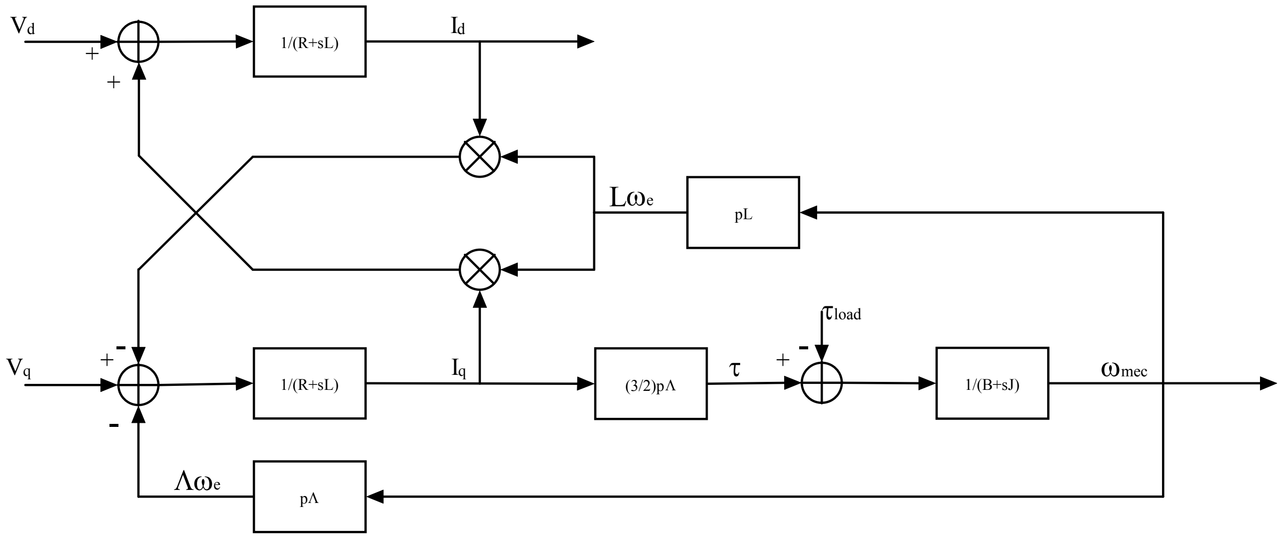
These two equations represent the mathematical motor model.

A control algorithm which wants to produce determined currents in the (d, q) system must impose voltages given from the formulas above.
This is ensured by closed loop PI control on both axis “d” & “q” (Proportional Integral).
Since there is a mutual influence between the two axes, decoupling terms can be used.

In the block scheme, the mechanic part is included, “p” is the number of pole pairs, while “B” represents friction, “J” the inertia, “τ_{load}“ the load torque and “τ” the motor torque.

$$\tau = \frac{3}{2} \times p \times \Lambda$$

The angular speed ω is represented in the scheme as ω_e to distinguish the electrical speed from the mechanical one.



Let's now consider the equations we have seen in (α,β) system:

$$v_\alpha = R_S i_\alpha + \frac{d\lambda_\alpha}{dt}$$

$$v_\beta = R_S i_\beta + \frac{d\lambda_\beta}{dt}$$

These equations show that magnetic flux can be obtained from applied voltages & measured currents simply by integration:

$$\lambda_\alpha = \lambda_{\alpha 0} + \int_0^t (v_\alpha - R_S i_\alpha) dt$$

$$\lambda_\beta = \lambda_{\beta 0} + \int_0^t (v_\beta - R_S i_\beta) dt$$

Furthermore:

$$\Lambda_m \cos(\vartheta) = \lambda_\alpha - L i_\alpha$$

$$\Lambda_m \sin(\vartheta) = \lambda_\beta - L i_\beta$$

As the phase inductance L is normally small, we can neglect the inductance contribution in the equation. So we get:

$$\lambda_\alpha = \Lambda_m \cos(\vartheta)$$
$$\lambda_\beta = \Lambda_m \sin(\vartheta)$$

So in the (α,β) system phase we obtain from the flux components:

$$\vartheta = \arctan\left({}^{\lambda_\beta}\!/\!_{\lambda_\alpha}\right)$$

The system speed ω can also be deduced from the derivative of the angle ϑ.

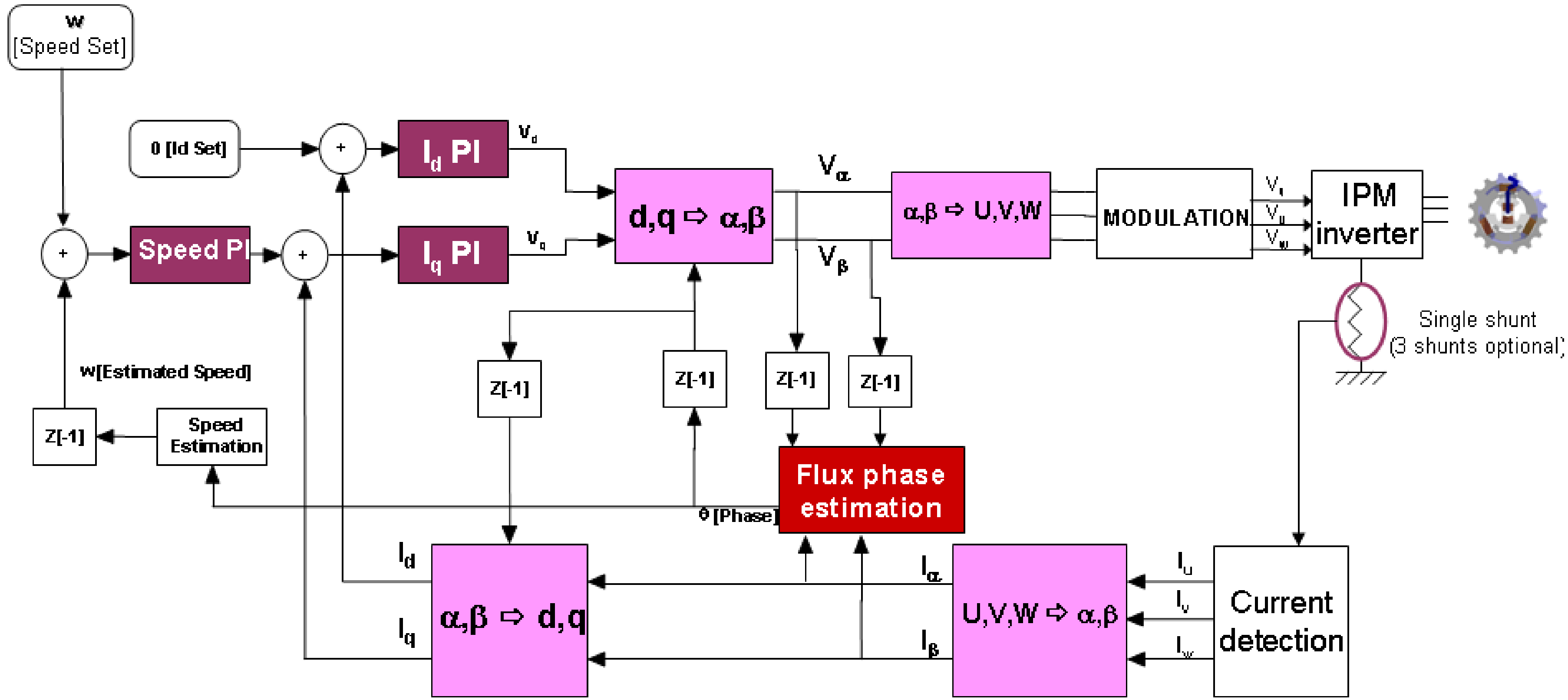
Based on this, a sensorless control algorithm was developed to give the imposed phase voltages, to measure phase currents, to estimate the angular position ϑ and finally the system speed:

$$w = \left(\frac{d}{dt}\vartheta\right)$$

Sensorless vector control algorithm using shunt current detection

Please, find below the FOC sensorless algorithm block diagram.

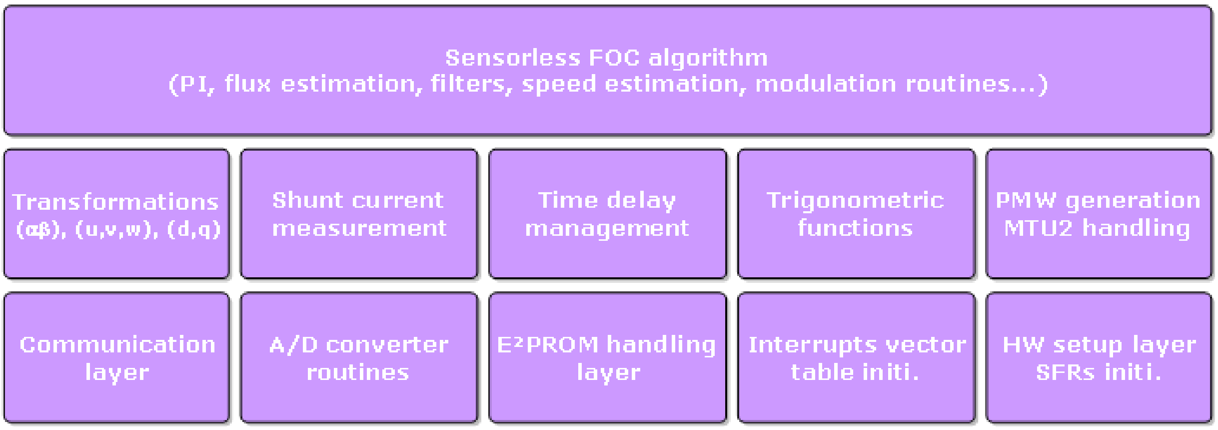
The only different between the three shunts and the single shunt configurations is in the “Current Detection” block, the rest of the algorithm remains the same.



Software Description in details

On MCRP05 this software is working both on SH7125 [50MHz] and on SH7085 [80MHz], in both cases the algorithm leaves enough time for other tasks as well as free resources [peripherals, I/O pins, FLASH and RAM] for other purposes.

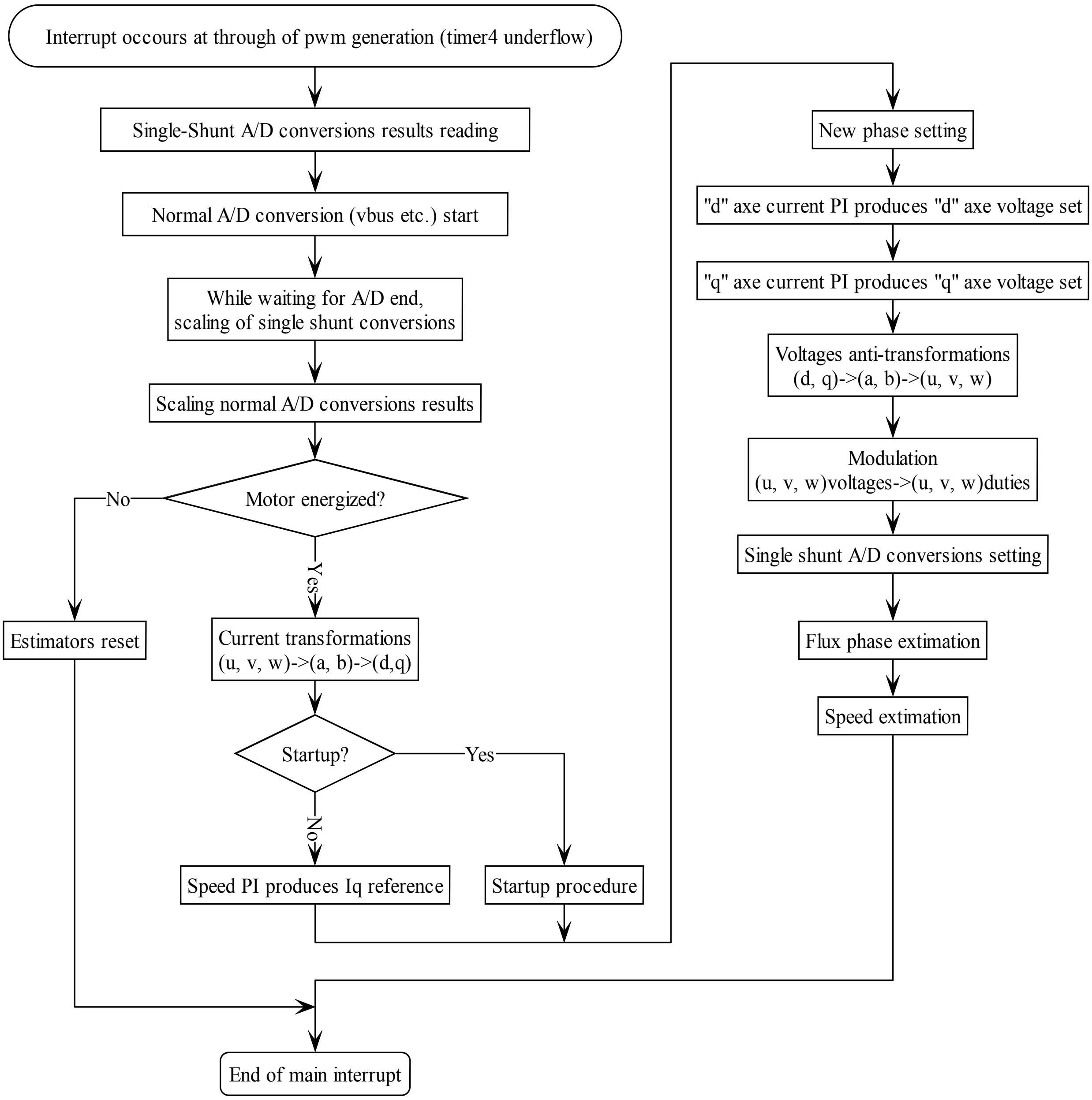
MCRP05: Software blocks



In particular the motor control library uses the following resources:

1) Flash memory usage: < 8Kbytes
2) RAM memory usage: ~1Kbytes
3) Interrupt Service Routines timing: < 35µs [@ 80MHz]

The following flow chart shows the software implementation of the motor control library.


Interrupt occours at through of pwm generation (timer4 underflow)
Single-Shunt A/D conversions results reading
Normal A/D conversion (vbus etc.) start
While waiting for A/D end,
scaling of single shunt conversions
Scaling normal A/D conversions results
Motor energized?
No
Yes
Estimators reset
Current transformations
(u, v, w)->(a, b)->(d,q)
Startup?
Yes
No
Speed PI produces Iq reference
Startup procedure
New phase setting
"d" axe current PI produces "d" axe voltage set
"q" axe current PI produces "q" axe voltage set
Voltages anti-transformations
(d, q)->(a, b)->(u, v, w)
Modulation
(u, v, w)voltages->(u, v, w)duties
Single shunt A/D conversions setting
Flux phase extimation
Speed extimation
End of main interrupt

Space vectors transformations in details

Find below the detailed equations used for the coordinates transformations.

$$g_\alpha = \frac{2}{3}(g_a - \frac{1}{2}g_b - \frac{1}{2}g_c) = g_a$$
$$g_\beta = \frac{2}{3}(\frac{\sqrt{3}}{2}g_b - \frac{\sqrt{3}}{2}g_c) = \frac{1}{\sqrt{3}}(g_b - g_c) = \frac{1}{\sqrt{3}}(g_a + 2g_b)$$

(a, b, c) → (α, β)

$$g_a = g_\alpha$$
$$g_b = -\frac{1}{2}g_\alpha + \frac{\sqrt{3}}{2}g_\beta = (-g_a + \sqrt{3}g_b)/2$$
$$g_c = -\frac{1}{2}g_\alpha - \frac{\sqrt{3}}{2}g_\beta = (-g_a - \sqrt{3}g_b)/2$$

(α, β) → (a, b, c)

$$g_d = g_\alpha \cos(\vartheta) + g_\beta \sin(\vartheta)$$
$$g_q = -g_\alpha \sin(\vartheta) + g_\beta \cos(\vartheta)$$

(α, β) → (d, q)

$$g_\alpha = g_d \cos(\vartheta) - g_q \sin(\vartheta)$$
$$g_\beta = g_d \sin(\vartheta) + g_q \cos(\vartheta)$$

(d, q) → (α, β)

$$g_d = \frac{2}{3}(g_a \cos(\vartheta) + g_b \cos(\vartheta - 2\pi/3) + g_c \cos(\vartheta - 4\pi/3))$$
$$g_q = -\frac{2}{3}(g_a \sin(\vartheta) + g_b \sin(\vartheta - 2\pi/3) + g_c \sin(\vartheta - 4\pi/3))$$

(a, b, c) → (d, q)

$$g_a = g_d \cos(\vartheta) - g_q \sin(\vartheta)$$
$$g_b = g_d \cos(\vartheta - 2\pi/3) - g_q \sin(\vartheta - 2\pi/3)$$
$$g_c = g_d \cos(\vartheta - 4\pi/3) - g_q \sin(\vartheta - 4\pi/3)$$

(d, q) → (a, b, c)

$$potenza_{d,q} = potenza_{\alpha,\beta} = \frac{2}{3}potenza_{a,b,c}$$

$$\begin{aligned} u_a &= U\cos(\omega t + \varphi_0) \\ u_b &= U\cos(\omega t + \varphi_0 - 2\pi/3) \\ u_c &= U\cos(\omega t + \varphi_0 - 4\pi/3) \end{aligned} \leftrightarrow \begin{aligned} u_\alpha &= U\cos(\omega t + \varphi_0) \\ u_\beta &= U\sin(\omega t + \varphi_0) \end{aligned} \leftrightarrow \begin{aligned} u_d &= U\cos(\varphi_0) \\ u_q &= U\sin(\varphi_0) \end{aligned} \qquad (\vartheta = \omega t)$$

PWM Modulation technique

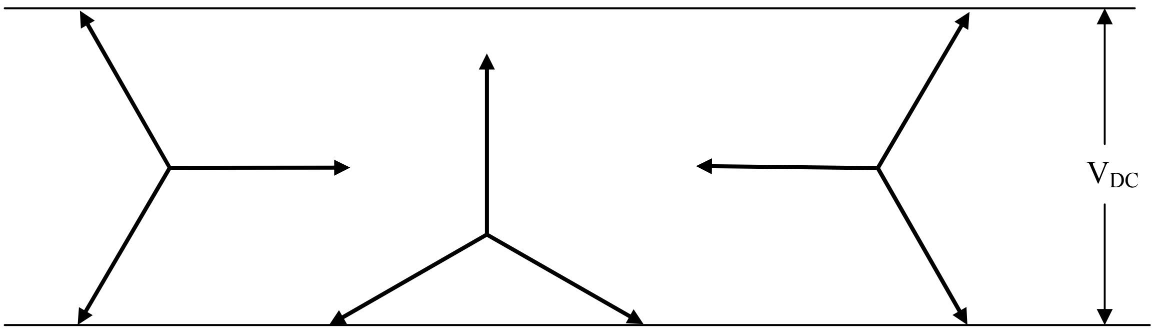


Figure X.X: geometrical representation of the rotating star

V_{DC} is the bus voltage.

The modulation method used has a very important advantage: one of the three duty cycles is always zero.

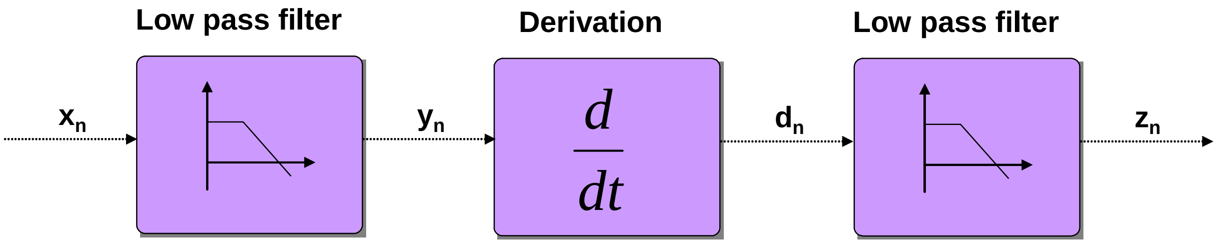
It means that the switches commutations are reduced by a factor of 30%, with a significant reduction of switching losses, so higher system efficiency.

The star-centre is not at a fixed voltage value, but describes a curve composed by circle arcs.

The maximum RMS output value we can obtain with this method is equal to the value that can be reached with space vector modulation and other methods.

The other known methods don't allow such reduction of the power consumption at low voltage amplitude.

Flux Phase estimation technique



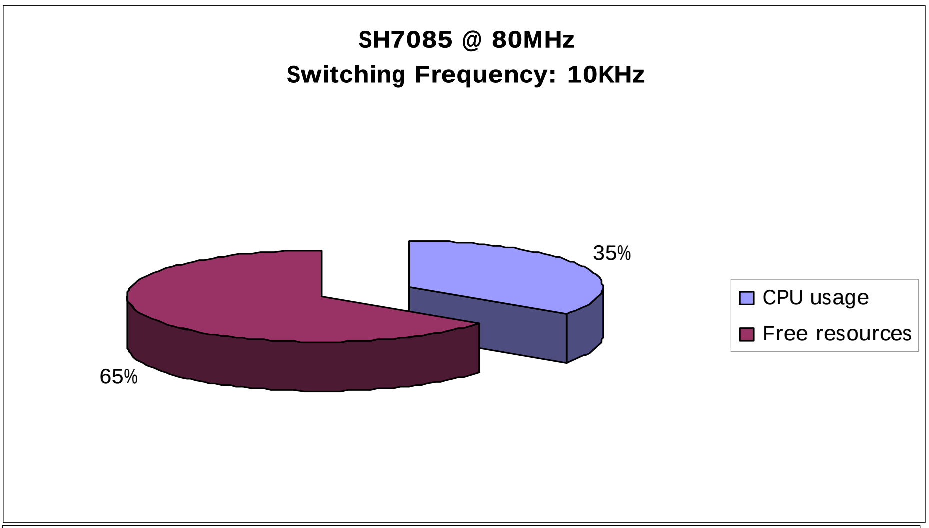
$y_n = K \times y_{n-1} + x_n$

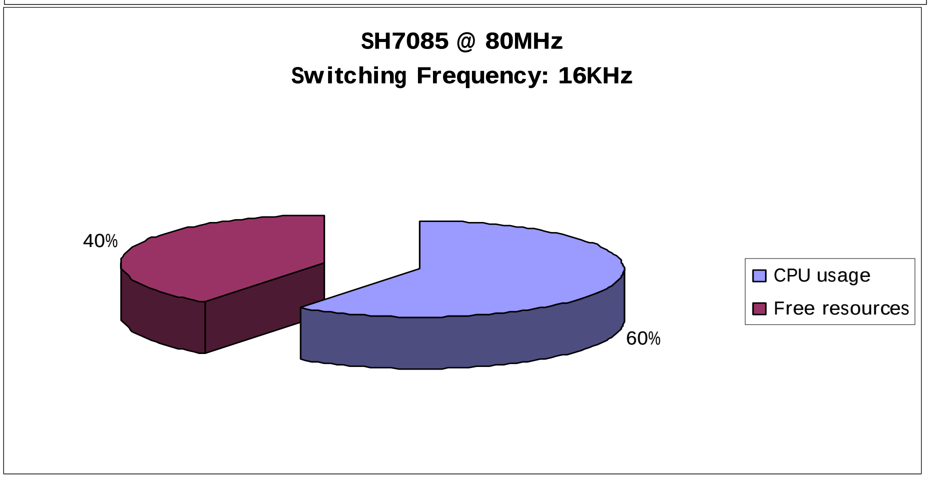
with $K = \frac{1023}{1024}$

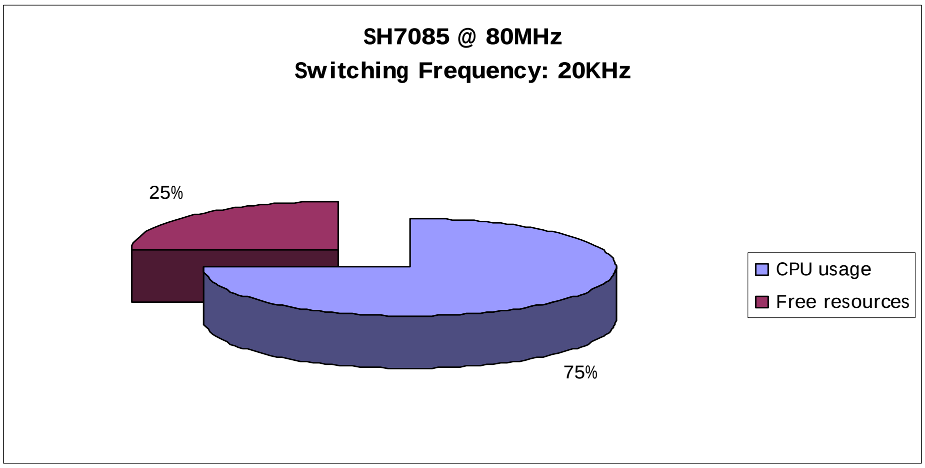
$d_n = y_n - y_{n-4}$

$z_n = K \times z_{n-1} + d_n$

MCRP05 – Performance figures



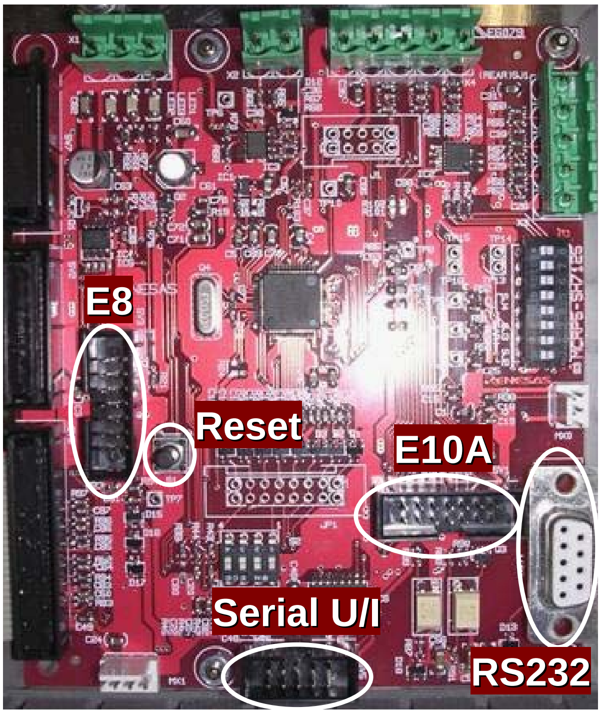




Developing using the MCRP05

On the SH7125 MCU boards, two different connectors are visible: one if for the E8 tool and the other one for E10A. Please be very careful when connected the tool to the MCRP05.

Furthermore, an isolated oscilloscope must be used if any high voltage is connected to the power stage board.



MCRP05 Safety considerations

MCRP05 is designed as a demonstration and development set. The case is delivered with a compact external power supply providing low voltages (5V, 15V, 23V).

The DC Bus voltage is 23V to guarantee any electric shock during demonstration.

The use of no other external energy sources guarantees that no electrical shocks are possible when using MCRP05 with E10A emulator or with a PC connected.

Any other possible use is not supported and should be avoided.

The X1 connector of the power stage is connected to the DC power Bus. It is provided only for test purposes to connect any other specific motors and any other DC bus voltage.

Please be aware that the power bus reference (-VBUS) is directly connected to the MCU board ground. By using the E10A emulator, it is connected directly with the PC ground.

It’s strongly recommended to use a transformer to insulate the board from the PC when it’s connected to the RS232.

The RS232 interface is electrically insulated (opto-coupled) from the rest of the demo set, but for safety purposes it must be considered NOT insulated.

Encoder & tachometer interfaces

For the development of the platform, an encoder and current transducers (LEM) were used. That's why it is possible to connect any five-wires encoder to the platform and adapt the software source code to enable the function.

A quadrature encoder can be used to detect the motor speed. It can be connected to the X4 connector, as indicated in the figure.

The pin out is:

1) Encoder Ground
2) Encoder A
3) Encoder B
4) Encoder 0 (if the encoder uses a zero signal)
5) Encoder Positive supply (+5V)

In the MCRP05 software some routines for encoder reading are already done and can be found in "motorcontrol.c" file. They are:

- **void McrpLib_StartEnc(void)**: timer 1 settings (phase counting mode 1) for encoder input reading, timer start.
- **void McrpLib_ReadEnc(void)**: encoder reading.

In the same file "motorcontrol.c" can be found also some macros to define encoder type.

- The default setting is for a 4096 pulses/revolution encoder (1024 teeth).

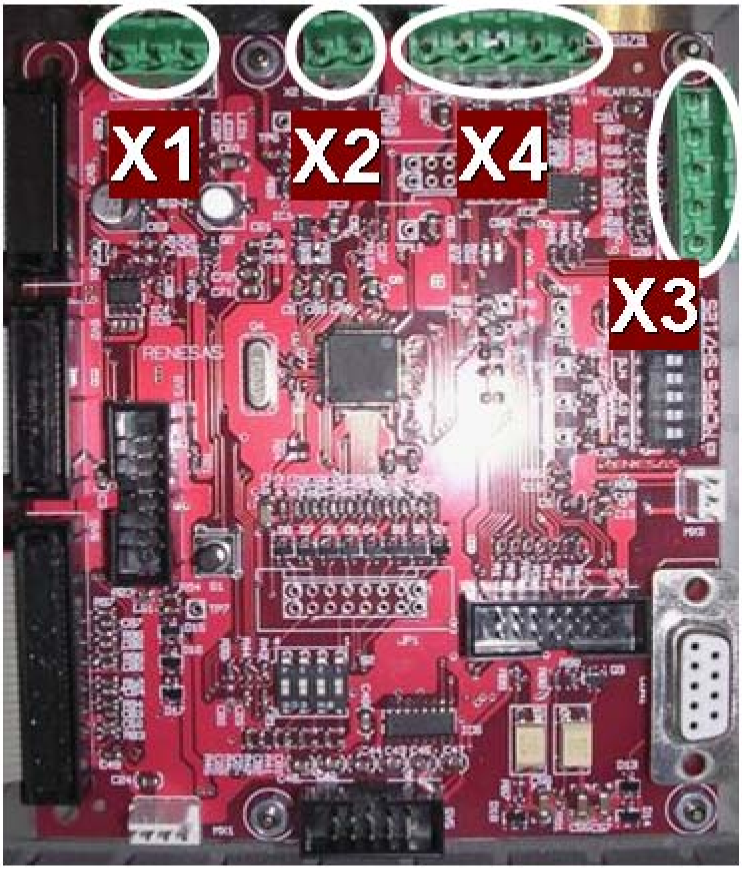
- The reading of the encoder pulses is performed by the hardware peripheral of the microcontroller.

- The software routine samples the result and applies the filters and the conversions. Please refer to the microcontroller manual for further details.

The hardware interface to connect a tachometer reading is also provided, using connector X2.

Please have a look at the figure below: the connector X2 is a two pins connector between the connect X1 (three pins) and X4 (five pins).

No software interface is actually provided.

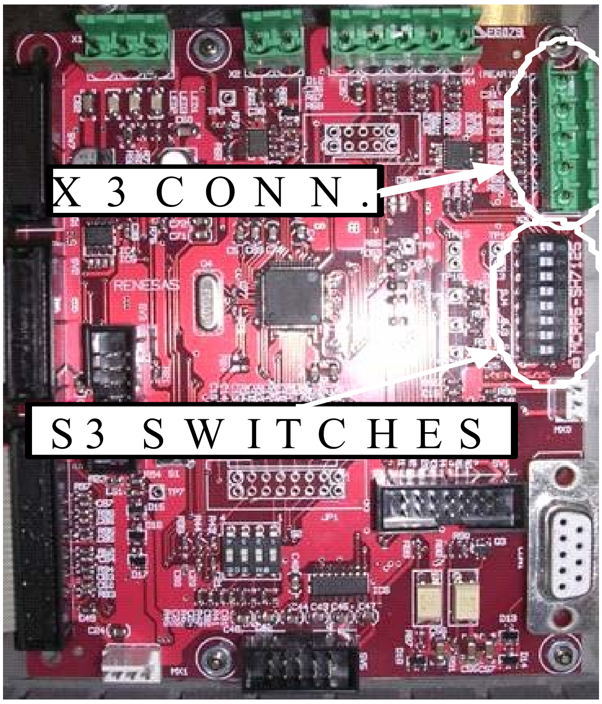


Hall sensors detection

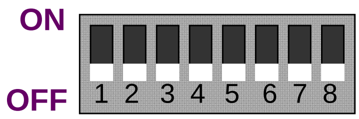
The connector X3 and the switches S3 can be used to select the detection of hall sensors signals for BLDC motor control.

The software is not provided yet. Switches S3 can also be used to select HW commutation signals from power stage, for dead time compensation. Please refer to the hardware drawings for more details.

The S3 DIP-switch is used to select between thee options: a fully sensorless option (by default), a sensorless using back-EMF approach where the back-EMF signals are connected to the MCU and finally the Hall sensors approach connected directly to the MCU.

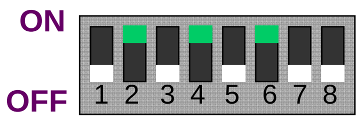


Fully sensorless
Default configuration



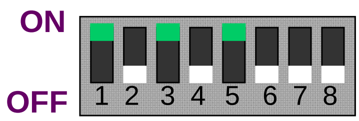
S3 Switch
CPU board

Sensorless Back-EMF signals enable



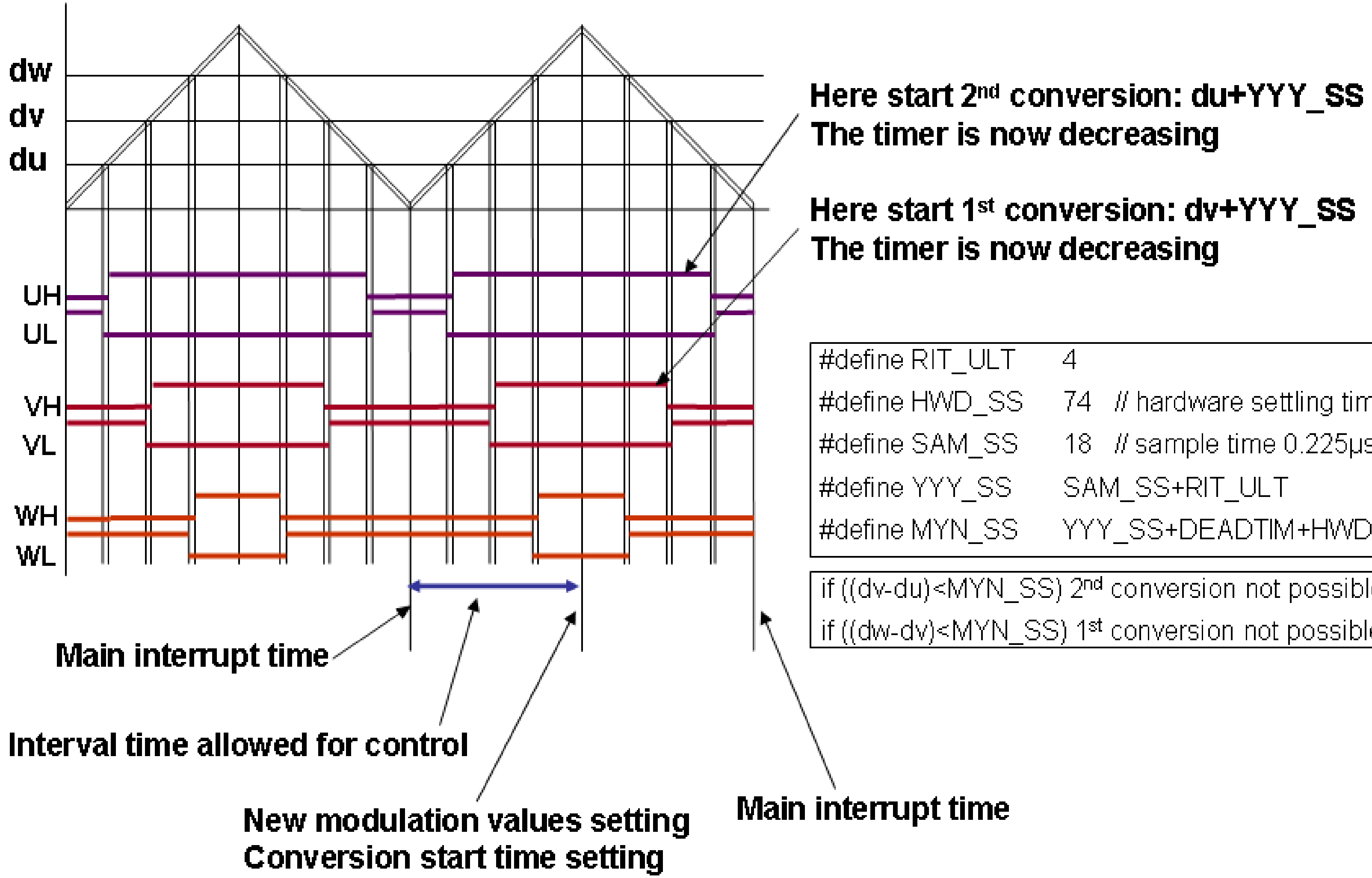
S3 Switch
CPU board

Hall sensors inputs enable



S3 Switch
CPU board

Single Shunt Current Detection




```
#define RIT_ULT     4
#define HWD_SS      74   // hardware settling time 0.925µs
#define SAM_SS      18   // sample time 0.225µs
#define YYY_SS      SAM_SS+RIT_ULT
#define MYN_SS      YYY_SS+DEADTIM+HWD_SS
```

```
if ((dv-du)<MYN_SS) 2nd conversion not possible
if ((dw-dv)<MYN_SS) 1st conversion not possible
```

Selection between Single & three shunts

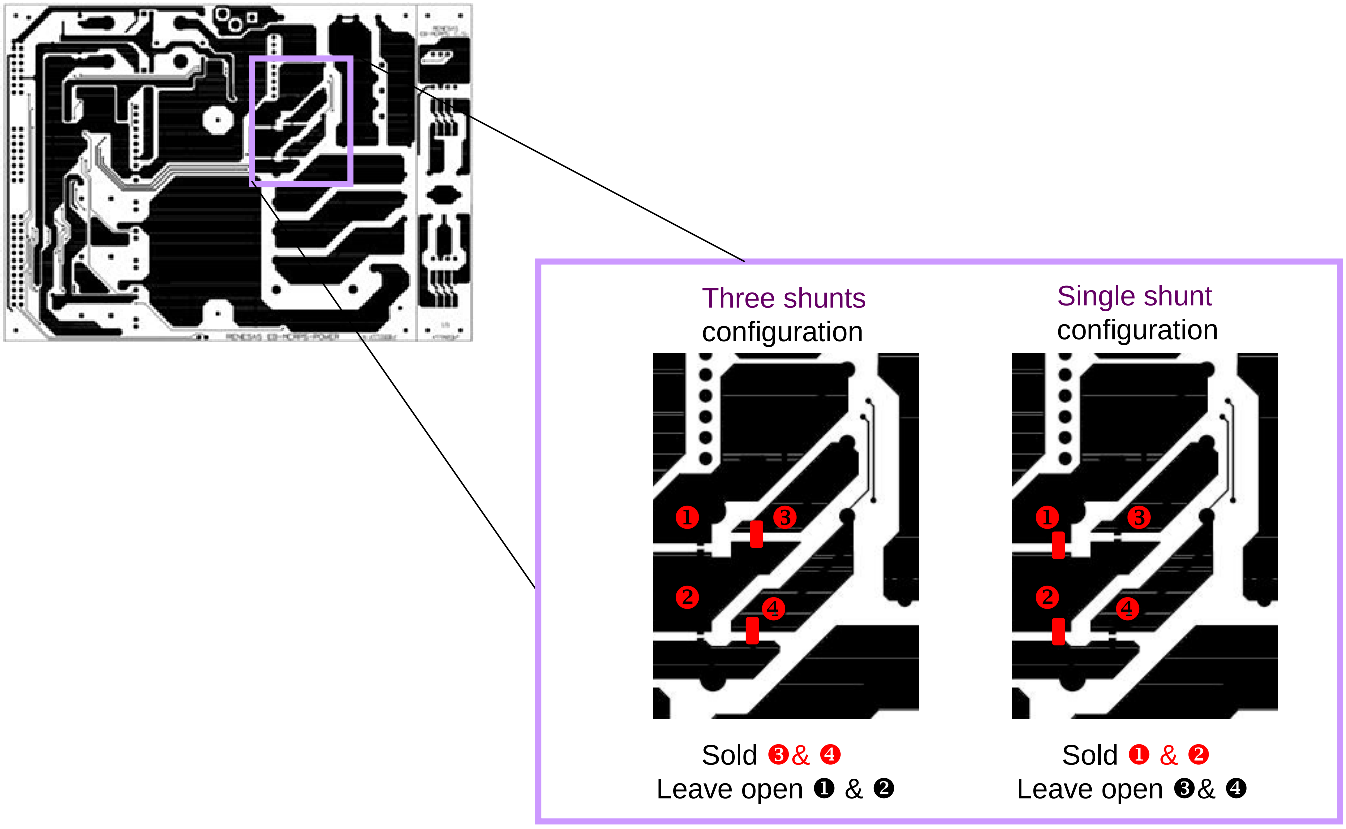
In order to change between single shunts to three shunts, there are two operations to make:

1) On the back side of the power stage, two soldering points are use to enable of disable the three shunts or single shunt current detection (see below the figure)

2) On the software side in the “customize.h” file, please enable of disable the following switches:

//#define	SINGLESHUNT	Only one of the “define” should remain commented
#define	THREESHUNTS	

Back side of the power stage board



PWM switching frequency and timings

The PWM switching frequency can be adjusted by the user using the macro **PWM_FRE** in the file called “customize.h” to fulfil the application requirements.

Two possible frequencies are selectable:

1) 10kHz: higher noise but higher efficiency
2) 20kHz: less noise & better sin wave shape

The algorithm sampling period is fixed to 100µs (10KHz) and the main interrupt is related with the PWM frequency.

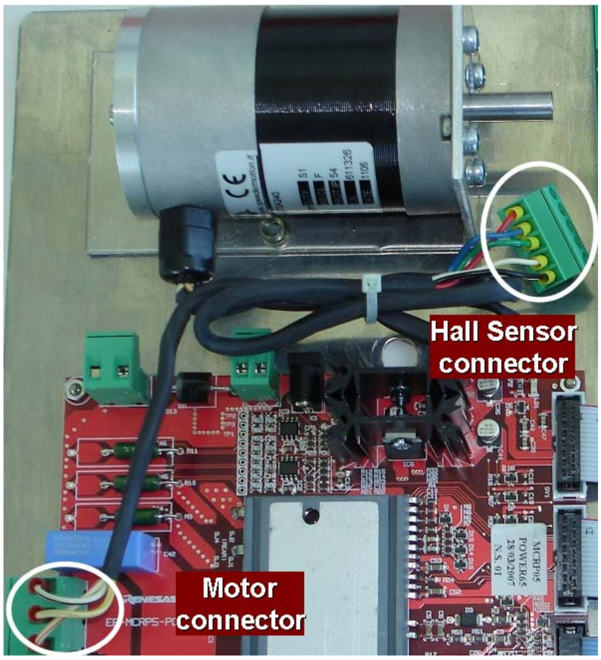
Thanks to the interrupt skipping facility of the MTU2 peripheral, it becomes easy to adjust the application software to 10KHz or 20KHz.

Other PWM switching frequency values can be obtained by directly modifying the macro called **SEMIPER** (half PWM period in MTU2 clock cycles units), but it is not recommended as the overall algorithm behaviour is affected.

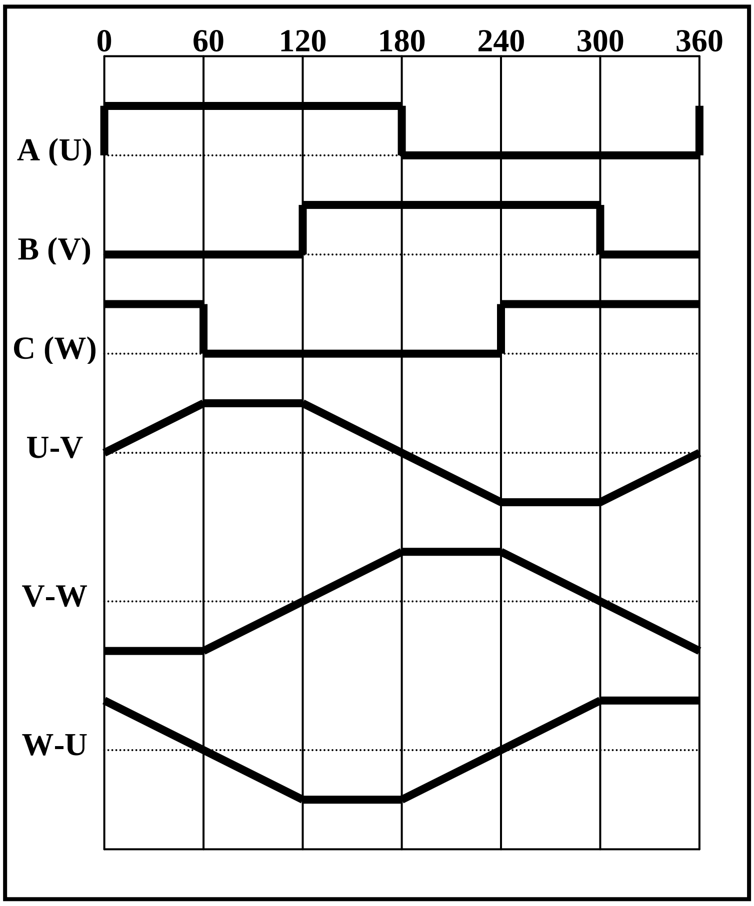
The timing of the main program is regulated by the macro **NUM_INT** in “motorcontrol.c” file.

The value of **NUM_INT** regulates the number of interrupts in the main loop. Such macro can be adjusted but it will affect all the timings of the routines called in main program.

Motor cables colours and description



- **U** Phase (power) **WHITE/RED**
- **V** Phase (power) **WHITE /YELLOW**
- **W** Phase (power) **WHITE /BLACK**



- Hall **A** (U) **GREEN**

(gives the sign of U-V back-EMF)

- Hall **B** (V) **WHITE**

(gives the sign of V-W back-EMF)

- Hall **C** (W) **BLUE**

(gives the sign of W-U back-EMF)

- Hall **GND** **BLACK**

- Hall **+VCC** **RED**

MCRP05 – Software tuning using the “customize.h” file

The “customize-h” file is a very useful and flexible way to adapt the software without entering into the code itself.

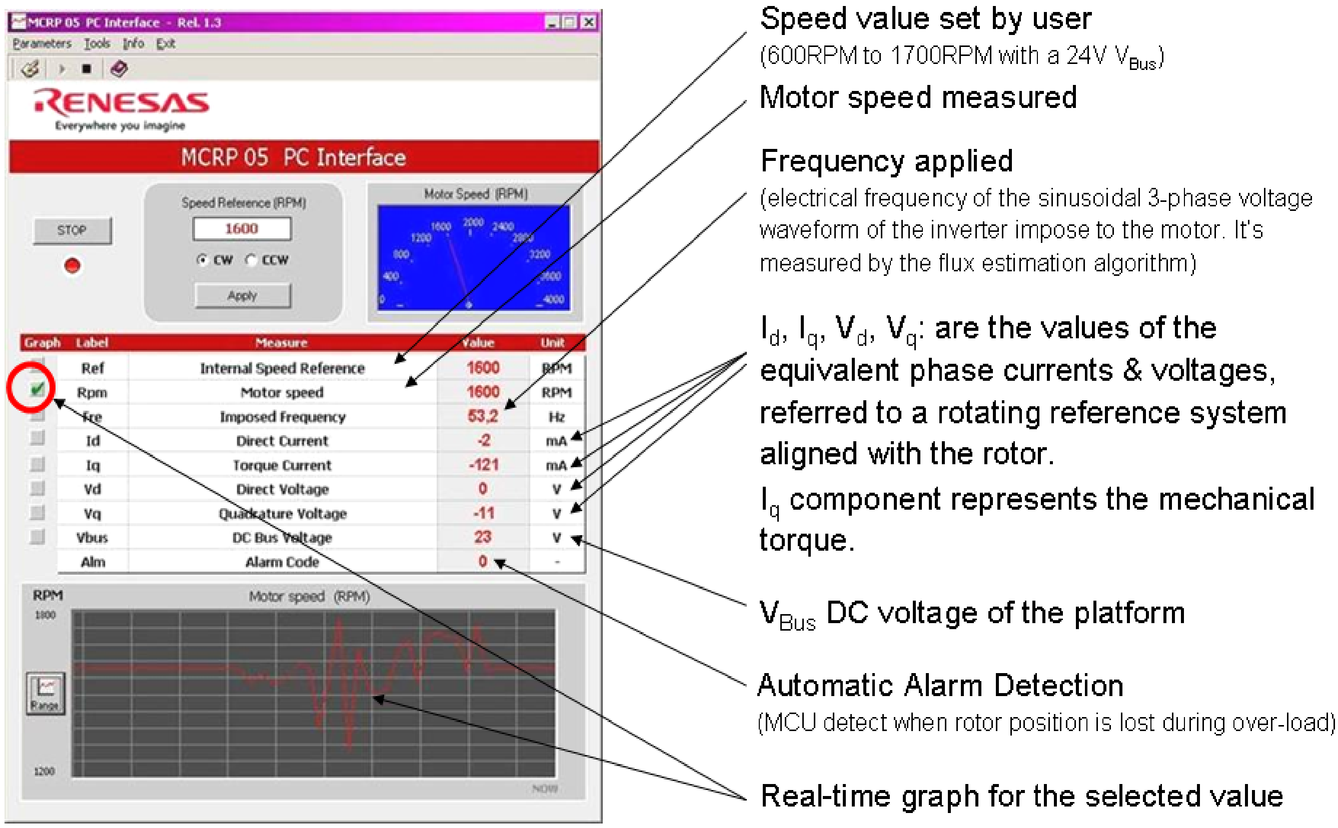
By commenting or modifying some lines, the complete system can be adapted to the user needs and is perfect for any platform evaluation.

#define SINGLESHUNT //#define THREESHUNTS	Select one shunt or three shunts for current detection
#define PWM_FREQ_CUSTOM 20000	PWM frequency modulation: between 3KHz and 20KHz
#define POSCURR	Selects sign of the current read through the shunt and the related amplifier stage. When using the MCRP05 schematics this line must be left as it is. When the positive input of the OpAmp is connected to GND this line must be commented.
#define EEPROM_USED	Enable the use of the external E^2PROM
#define DISPLAY_USED	Enable display usage
#define MCRP05_SCI0_CONNECTION	Enable SCIO for external connection
#define SAMPLE_FREQ_CUSTOM 10000 #define STARTUP_RAMPTIME_CUSTOM 800	Control loop time in Hz between 2500Hz up to 10KHz Startup ramp time in ms
#define RPM_MIN_CUSTOM 600 #define RPM_MAX_CUSTOM 4500 #define R_ACC_CUSTOM 1000 #define C_POLI_CUSTOM 2 #define ID_NOM_CUSTOM 0 #define IQ_NOM_CUSTOM 30 #define R_STA_CUSTOM 7 #define KP_CUR_CUSTOM 150 #define KI_CUR_CUSTOM 100 #define KP_VEL_CUSTOM 30 #define KI_VEL_CUSTOM 20	min speed in RPM max speed in RPM acceleration ramp in RPM/sec polar pairs number flux current max torque current in $A_{rms}/10$ stator phase resistance in $\Omega/10$ K prop. current control K integ. current control K prop. speed control K integ. speed control
#define DEADTIM_CUSTOM 2.0	Dead-time value in µs @40MHz
#define RSHUNT_CUSTOM 100.0 #define RSGAIN_CUSTOM 5000.0 #define AVCC_CUSTOM 5000.0	Shunt value in mΩ Circuit gain x1000 A/D Range in mV
#define RVBUS1_CUSTOM 400000.0 #define RVBUS2_CUSTOM 4700.0	Split resistor 1 in Ω Split resistor 2 in Ω
#define VIGBTV_CUSTOM 800.0 #define VDIODOV_CUSTOM 1400.0	V_{CESAT} of the IGBT in mV Free-wheel diode forward voltage in mV
#define FIRST_FLUX_LOWPASS_TIME_CUSTOM 10 #define DERIVATIVE_TIME_CUSTOM 1 #define LAST_FLUX_LOWPASS_TIME_CUSTOM 10	Flux phase estimation is made through following steps: 1) first low pass filter, 2) derivative, 3) last low pass filter
#define FIRST_SPEED_LOWPASS_TIME_CUSTOM 5 #define SECOND_SPEED_LOWPASS_TIME_CUSTOM 4 #define THIRD_SPEED_LOWPASS_TIME_CUSTOM 3	Filters parameters

PC Interface – Platform tuning & monitoring

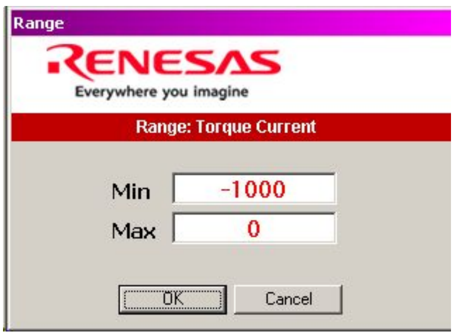
A complete PC based interface is available to display the main values & measurements like the motor speed, the motor currents, the torque, the DC Bus voltage, etc.

Please find below the screen shot of the PC interface connected via RS232 link to the MCRP05.



By selection the label on the right hand side, the graph will automatically display the real-time values, so it becomes easy to analyse the influence of the motor load on the motor speed.

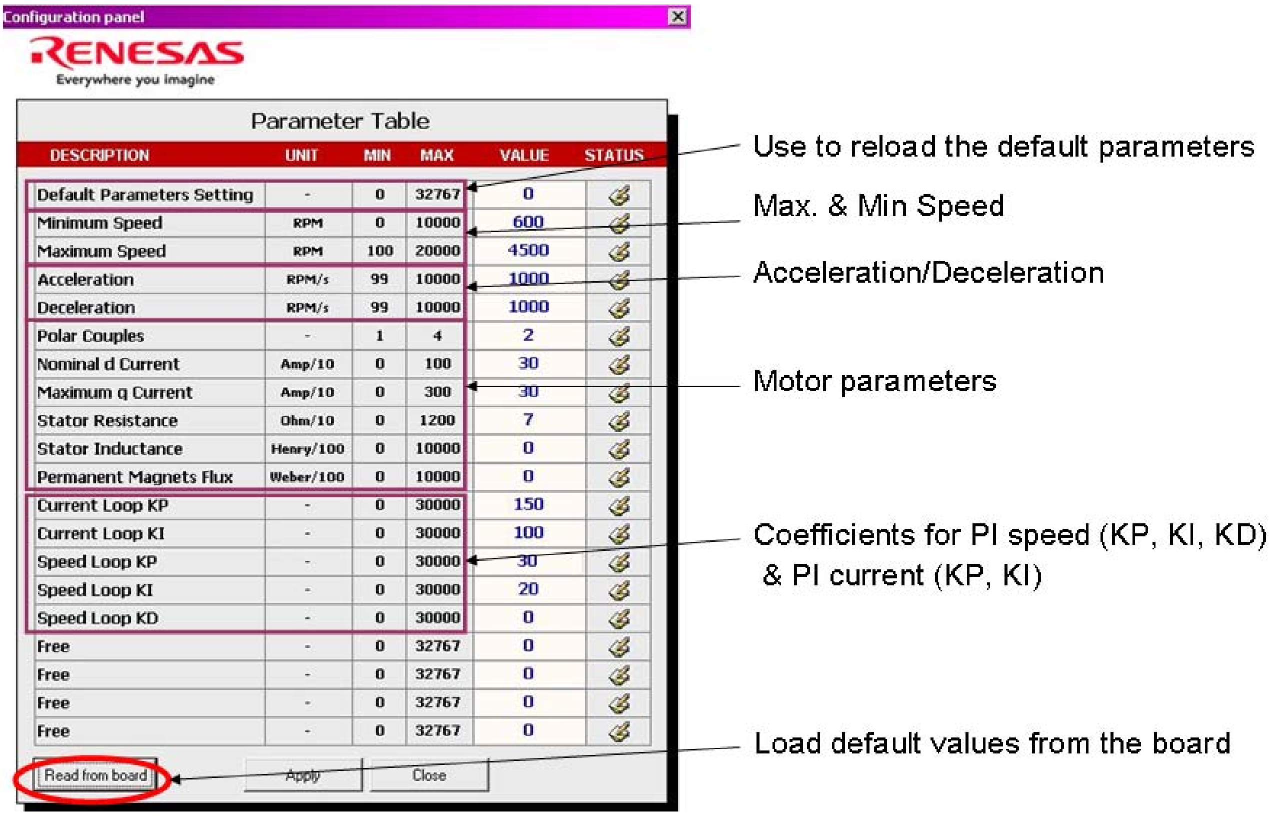
The range of the graph can be easily modified by clicking the button “Range”:



As soon as reference speed is set, whatever the torque required the system will keep a very accurate speed showing a fast reaction time and good system dynamics.

Furthermore, the software running on the platform is using system parameters that may be modified via the PC user interface.

In the main menu, it is possible to display the platform **parameters** & modify them.



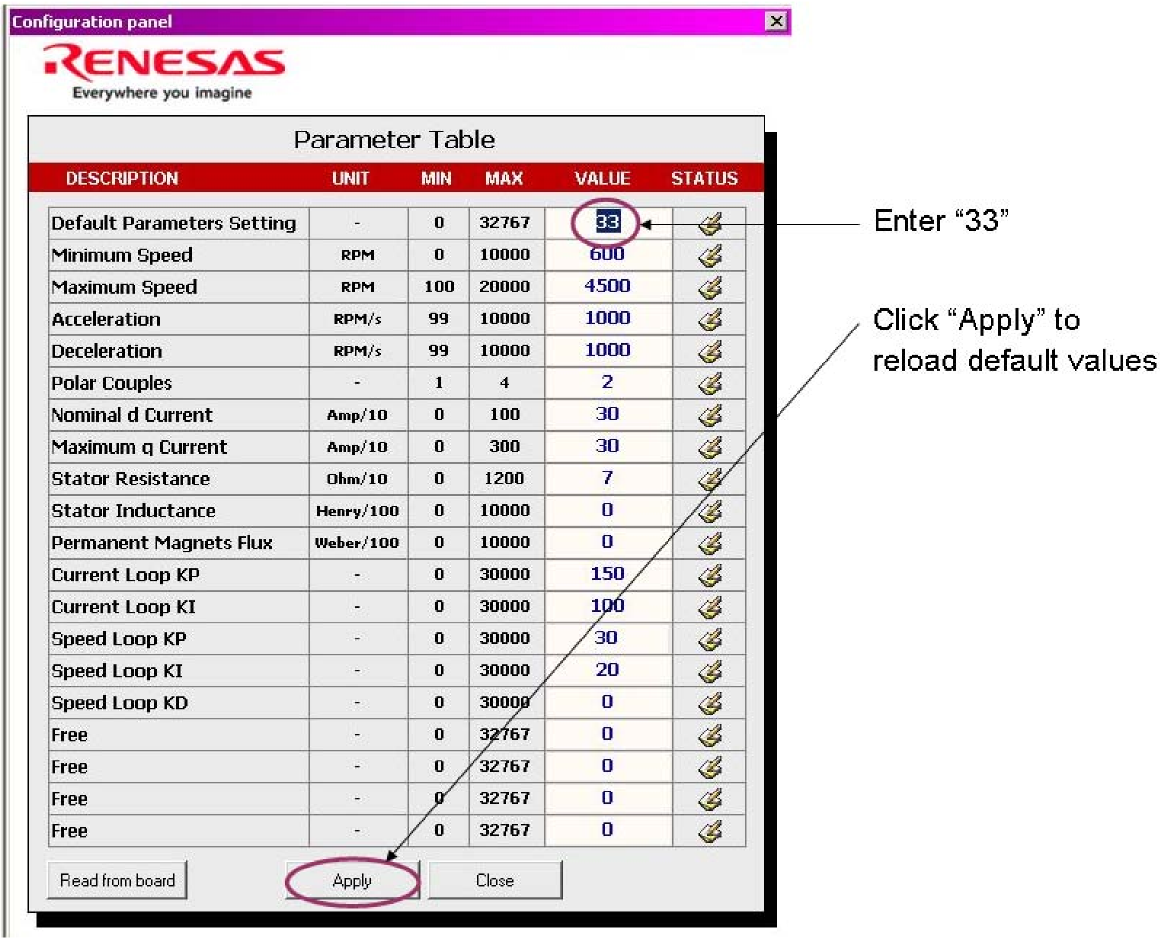
DESCRIPTION	UNIT	MIN	MAX	VALUE	STATUS
Default Parameters Setting	-	0	32767	0	
Minimum Speed	RPM	0	10000	600	
Maximum Speed	RPM	100	20000	4500	
Acceleration	RPM/s	99	10000	1000	
Deceleration	RPM/s	99	10000	1000	
Polar Couples	-	1	4	2	
Nominal d Current	Amp/10	0	100	30	
Maximum q Current	Amp/10	0	300	30	
Stator Resistance	Ohm/10	0	1200	7	
Stator Inductance	Henry/100	0	10000	0	
Permanent Magnets Flux	Weber/100	0	10000	0	
Current Loop KP	-	0	30000	150	
Current Loop KI	-	0	30000	100	
Speed Loop KP	-	0	30000	30	
Speed Loop KI	-	0	30000	20	
Speed Loop KD	-	0	30000	0	
Free	-	0	32767	0	
Free	-	0	32767	0	
Free	-	0	32767	0	
Free	-	0	32767	0	

Please find above the default values for each parameter. Note that that some coefficients with “0” as values are not used like “the speed loop KD”.

The stator resistance is a key parameter that needs to be adapted to each motor type. After changing the value, please click on “Apply” and perform a board reset to start the system with the new parameters.

If any issues are happening during the programming of the board or during the parameters modification, a simple way is to write the magic value “33” in the first line: “Default Parameters Setting”.

Please find below the screen shot with the details.



Website and Support

Renesas Technology Website
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Inquiries
http://www.renesas.com/inquiry
csc@renesas.com

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